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Imaging Planetary Nebulae with Herschel-PACS and SPIRE *

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Abstract. In this paper we will discuss the images of Planetary Nebulae that have recently been obtained with PACS and SPIRE on board the Herschel satellite. This comprises results for NGC 650 (the little Dumbbell nebula), NGC 6853 (the Dumbbell nebula), and NGC 7293 (the Helix nebula).

1. Introduction

We have obtained Herschel PACS and SPIRE images of planetary nebulae (PNe) as part of the MESS (Mass loss of Evolved StarS) guaranteed time key program. The aims of this program are threefold: 1) study the time dependence of the mass loss process via a search for shells and multiple shells, 2) study the dust and gas chemistry as a function of progenitor mass, and 3) study the properties and asymmetries of a representative sample of evolved objects. This program will be discussed in more detail in a forthcoming paper (Groenewegen et al. 2010). During the science demonstration phase of Herschel we obtained PACS and SPIRE images of NGC 6720, which have been discussed in van

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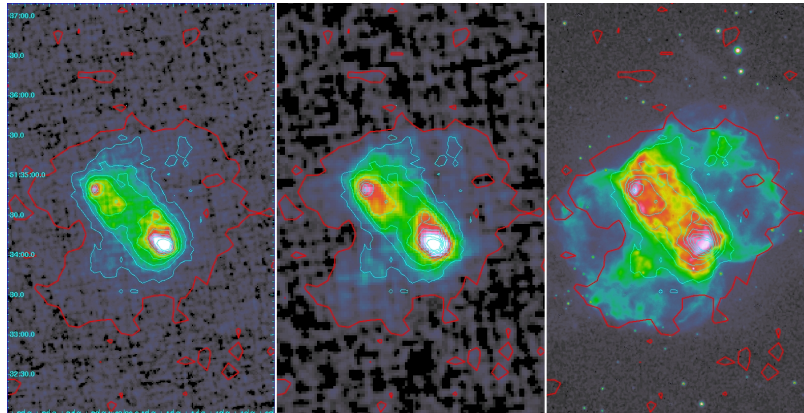


Figure 1. NGC 650. Left: PACS 70 μm , middle PACS 160 μm , right: ground-based $\text{H}\alpha$ image (Lars Ø. Andersen, Lars Malmgren, Frank R. Larsen, NOT). A manual shift of 4.5'' was applied to the WCS of the PACS images.

Hoof et al. (2010). The detailed match between the H_2 and dust emission in this object appears to be the first observational evidence that H_2 forms on oxygen-rich dust. The most plausible scenario is that the H_2 resides in high density knots that were formed after the recombination of the gas started when the central star entered the cooling track. Models indicate that a substantial amount of H_2 could have formed since that time and that the formation may still be ongoing at this moment.

Below we will present preliminary reductions of PACS and SPIRE data of 3 other PNe that we obtained during the routine phase.

2. Data Reduction

Poglitsch et al. (2010) describe the standard data reduction scheme for PACS scan maps from so-called “Level 0” (raw data) to “Level 2” products. The level 1 and 2 products that are part of the data sets from the Herschel science archive have been produced by execution of these standard pipeline steps. We do not use the standard products, but use an adapted and extended version of the pipeline script suited to our needs starting from the raw data. In particular the deglitching step(s), and the “high pass filtering” need special care.

When the central source is bright, the deglitching task incorrectly masks a significant number of frames of the source as glitches. A second pass (called “2nd level deglitching”) is needed to remedy this. The purpose of the high pass filter is to remove the $1/f$ noise from the images. At the moment the task is using a median filter, which subtracts a running median from each readout. This works well for point sources, but causes significant problems for extended sources (resulting in negative “shadows” in the image). To prevent the artifacts, any part of the source needs to be masked from the median filter. We are currently still experimenting with various algorithms to achieve this in an optimal way. We are also looking into using MadMap as an alternative algorithm. In addition, as the standard pipeline script operates on a single Astronomical Observation Request (AOR), while our observations are always the concatenation of 2 AORs (a scan and a cross-scan) an additional step is also needed to combine the two

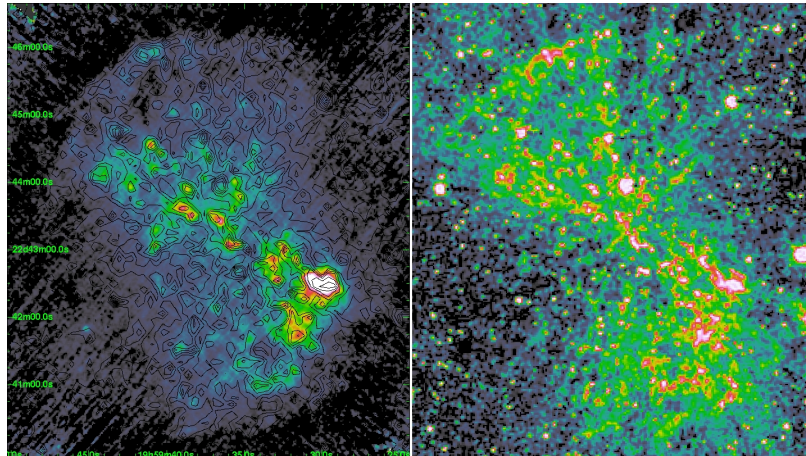


Figure 2. NGC 6853. Left: PACS 70 μm with H_2 contours overlaid, right: ground-based H_2 2.12 μm image (I. Gatley, M. Merrill, NOAO).

scans. The pointing accuracy of Herschel is within specifications, but is however not negligible compared to the PACS beam size. Hence manual adjustments of the world coordinate system (WCS) may also be necessary when comparing with other (ground-based) images. A more in-depth discussion of the PACS data reduction will be given in Groenewegen et al. (2010).

The standard SPIRE photometer data processing pipeline, described by Griffin et al. (2008, 2010), is sufficient to reduce our SPIRE photometric imaging data. The calibration steps for these data are described by Swinyard et al. (2010).

In Figs. 1, 2, and 3 we present preliminary reductions of the PACS scan maps of NGC650, NGC 6853, and NGC 7293. The reduction of the SPIRE maps of NGC 7293 is final.

3. Outlook

Both NGC 7293 and NGC 6853 are well evolved PNe with central stars that are currently on the cooling track (O'Dell et al. 2007). So both nebulae are in a similar evolutionary state compared to NGC 6720. Especially NGC 7293 is almost an “older twin”. Also in these objects we see that the distribution of the H_2 closely follows the dust. This suggests that in these objects the H_2 has also been formed in high density knots. We will model these PNe in detail to test whether the scenario that we proposed in van Hoof et al. (2010) can also explain the H_2 formation in these objects. Also in NGC 650 we see that the gas and dust show a very similar distribution. It is not yet clear however if this H_2 formed in a similar fashion, or whether it is leftover AGB material.

In addition to the scan maps presented in van Hoof et al. (2010) and this paper, we will also obtain Herschel images of NGC 650 (SPIRE), NGC 3587 (PACS, SPIRE), NGC 6543 (PACS, SPIRE), NGC 6853 (SPIRE), NGC 7027 (PACS), IRAS 22036+5306 (PACS). For all targets we will obtain PACS images in the 70 and 160 μm bands, while SPIRE images will be obtained in all 3 bands: 250, 350, and 500 μm . The final goal of the program is to study the structures of their dust shells in order to learn about the (post-) AGB mass loss processes.

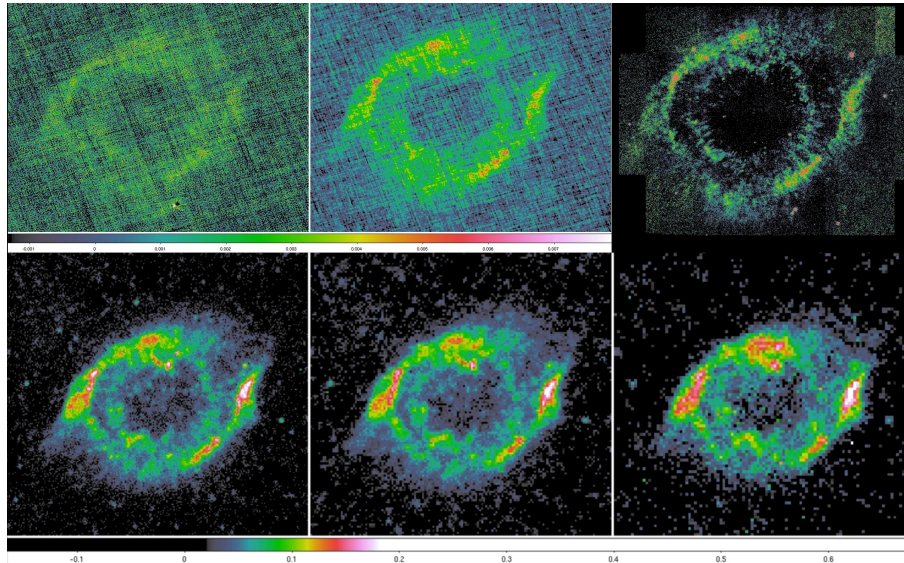


Figure 3. NGC 7293. Top row: PACS 70 & 160 μm , H₂ 2.12 μm (courtesy A. Speck, KPNO), bottom row SPIRE 250, 350 & 500 μm .

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